PROC. ENTOMOL. SOC. WASH.
82(1), 1980, pp. 117–123

THE ANTENNAL SENSE ORGANS OF THE PINK BOLLWORM, *PECTINOPHORA GOSSYPIELLA* (SAUNDERS) (LEPIDOPTERA: GELECHIIDAE)

B. J. Cook, R. L. Smith, and H. M. Flint

(BJC) Western Cotton Research Laboratory, Agricultural Research, Sci. and Educ. Admin., USDA. Present address: Veterinary Toxicology and Entomology Research Laboratory, Agricultural Research, Sci. and Educ. Admin., USDA, College Station, Texas 77840; (RLS) Department of Entomology, University of Arizona, Tucson, Arizona 85721; (HMF) Western Cotton Research Laboratory, Agricultural Research, Sci. and Educ. Admin., USDA, Phoenix, Arizona 85040.

Abstract.—The antennae of both sexes of the adult pink bollworm, *Pectinophora gossypiella* (Saunders), are divided into three principal parts: The basal segment (scape), the elongated second segment (pedicel), and the flagellum (composed of 40–46 subsegments). Five distinct classes of sensilla were found on the flagellomeres of the antennae of both male and female moths: Sensilla styloconica, sensilla chaetica, sensilla trichodea (two types), sensilla basiconica, and sensilla coeloconica. A specialized sensory structure on the apical subsegment was also observed in both sexes. The general surface geometry and distribution of these sensilla are descirbed. Sexual dimorphism was evident with male moths having slightly longer (56.1 μ ± 6.6) and more erect sensilla trichodea than females (43.1 μ ± 4).

It has long been recognized that the antennae of insects serve as major sensory organs though only in recent years has research interest been directed to the pheromone receptors found on these organs. Pheromone perception in the pink bollworms, *Pectinophora gossypiella* (Saunders), as in most Lepidoptera, seems to be exclusively associated with receptors on the antennae (Smith et al., 1978).

However, the external morphology of olfactory sense cells can be quite different, even within a species (Schneider and Steinbrecht, 1968). Consequently, some classification of the various types of antennal receptors in the pink bollworms was essential before commencing electrophysiological studies on single olfactory receptors. Moreover, the antennae perform many other important sensory functions besides olfaction. For example, mechanoreceptors, chemoreceptors, and receptors that detect temperature and humidity often have significant roles in antennal perception. Thus, a study of antennal sense organ morphology and distribution would give us some understanding of the total sensory repertoire inherent in these structures of the pink bollworms.

Materials and Methods

Freshly excised antennae from three-day-old laboratory-reared male and female pink bollworm moths (Western Cotton Research Laboratory, Phoenix, Arizona) were placed in a mixture of 3% glutaraldehyde, 2% paraformaldehyde, and 1% picric acid in a 0.05 M phosphate buffer pH 7.4. The antennae were allowed to remain in this fixative for one to three hours. After five rinses in the phosphate buffer over a period of one hour, the antennae were then placed in the same phosphate buffer containing 1% osmium tetroxide for two hours. This treatment was followed by five to ten standing rinses in distilled water for one hour. Once this procedure was complete, samples of the specimens were dehydrated in an ascending series of concentrations of ethanol, rinsed three times for 15 min in 100% acetone, and dried in a Denton®[1] critical point drier with liquid CO_2.

The dried specimens were either mounted on scanning electron microscope stubs with silver paint and coated with gold palladium, or treated with histological stains. An Advance Metals Research Corp. scanning electron microscope (AMR 1000A®) operated at 20 kv was used for observation. Further studies were conducted with a light microscope by using Slifer's (1960) crystal violet method to detect permeable sense organs.

Observations

The antenna of the pink bollworm consists of three principal parts: The two distinct basal segments, the scape and pedicel, and the flagellum which is composed of many small flagellomeres. The number of flagellomeres was variable in the randomly sampled antennae. The mean number and range for five male and five female moths were:

	Mean no. of subsegments	Range
Male	42	40–46
Female	44	43–46

Five distinct classes of sensory organs, according to the nomenclature of Schneider (1964), were identified on the flagellum. Each type will be described under separate headings below. Although most sense organs were

---

[1] This paper reports the results of research only. Mention of a proprietary product in this paper does not constitute a recommendation for use by the U.S. Department of Agriculture.

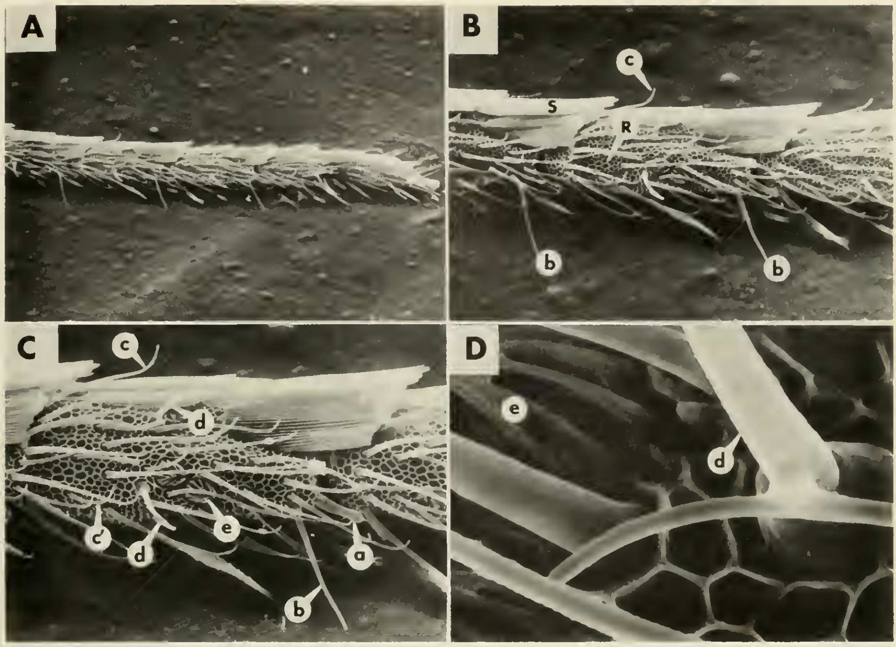

Fig. 1. Scanning electron micrographs of the antennal sense organs of the female pink bollworm. A, Five distal flagellomeres of the antenna (200×). B, Dorsal and ventral characteristics of three flagellar subsegments, scales (S) on dorsal surface, and reticular network (R) on ventral surface with prominent sensilla chaetica (400×). C, Close-up of 40th flagellomere (4th from apex) showing the five different sense organs present (800×). D, External fine structure of 40th flagellomere (8600×). Abbreviations: a = Sensillum styloconicum; b = sensillum chaeticum; c = sensillum trichodeum Type 1; c′ = sensillum trichodeum Type 2; d = sensillum basiconicum; e = sensillum coeloconicum.

Table 1. Lengths in micrometers of various sensilla between the penultimate and the 34th subsegment of the antenna of *Pectinophora gossypiella*.

	Males			Females		
Sensory Structure	Mean Length ±s.d.	Range	n	Mean Length ±s.d.	Range	n
Sensilla Styloconica	20.93 μ ± 1.86	16.71–24.43	39	19.53 μ ± 2.06	16.71–23.14	36
Sensilla Chaetica	43.89 μ ± 5.40	32.14–55.29	71	37.94 μ ± 3.41	29.57–43.11	53
Sensilla Trichodea	56.19 μ ± 6.61	41.14–70.71	120	43.11 μ ± 4.01	32.14–51.43	120
Sensilla[1] Coeloconica	8.72 μ ± 1.09	6.43–10.29	59	7.95 μ ± 0.86	6.43–10.29	34

[1] Mean diameter ± s.d.

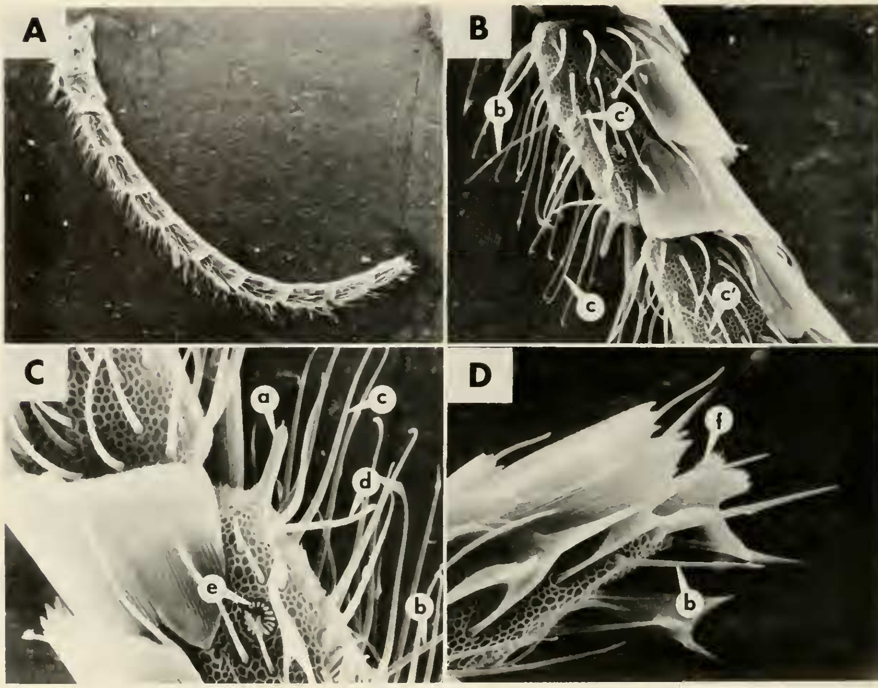

Fig. 2. Scanning electron micrographs of the antenna of the male pink bollworm. A, Ten distal flagellomeres of the antenna (100×). B, Dorsal and ventral aspects of a flagellomere (400×). C, Portions of two flagellomeres showing the five different sense organs (800×). D, Apical flagellomere showing terminal sense organ (1000×). Abbreviation: f = Terminal sense organ; other abbreviations as in Fig. 1.

found on the ventral surface of the antennae (Fig. 1A), an occasional sensillum trichodeum was located on the dorsal surface (Fig. 1B). As with other Lepidoptera (Jefferson et al., 1970), the dorsal surface is usually covered by overlapping scales (Fig. 1B). Scanning electron micrographs revealed that the surface of each flagellomere subsegment is covered by a delicate reticular network of minute ridges (Fig. 1B).

The apical subsegment on the antennae of both male and female moths has a bilobed protuberance at the tip (Fig. 2D). This structure is covered with fine spines and was surrounded by an array of four sensilla chaetica.

Sensilla styloconica.—These sensilla are stout cuticular pegs crowned by a sensory cone. Such pegs are found on the apical border of each flagellomere of both male and female pink bollworm moths (Fig. 1C). Generally, only a single sensillum styloconicum was detected on each subsegment. The mean length of these pegs was 20.9 μm in males and 19.53 μm in females as shown in Table 1.

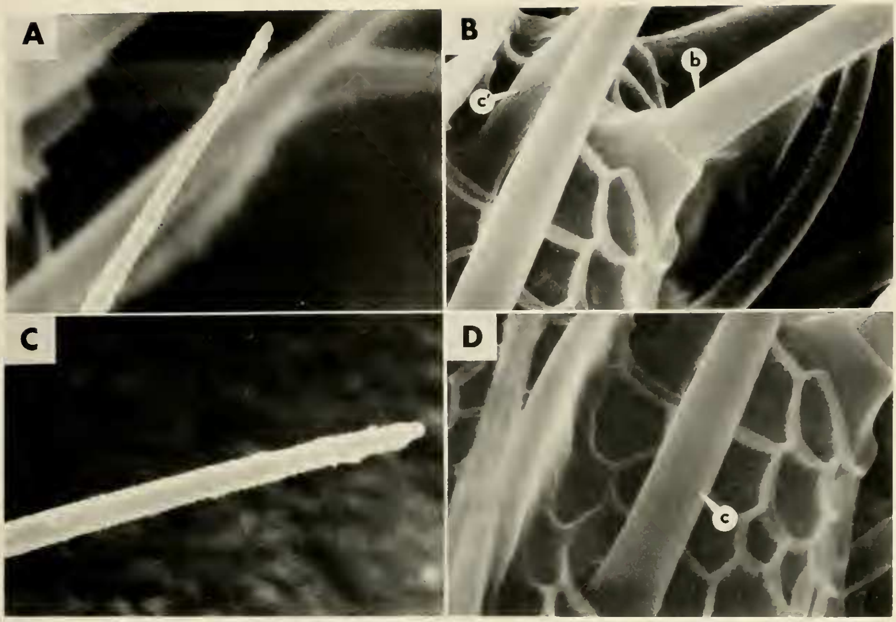

Fig. 3. Surface fine structure of sensilla trichodea and sensilla chaetica by scanning electron microscopy. A, Tip of sensillum trichodeum Type 1 (8600×). B, Base of sensillum chaeticum and sensillum trichodeum Type 2 (8600×). C, Surface contour of the tip of a sensillum chaeticum (8600×). D, Base of sensillum trichodeum Type 1 (8600×). Abbreviations as in Fig. 1.

Sensilla chaetica.—These relatively blunt sensory spines are found on the ventral surface of each subsegment. The spines are located near the distal border in females but are more centrally located in male moths. High magnification scanning electron micrographs showed that the surface of the spines is covered by radial ridges (Fig. 3C). These sensilla are inserted into round sockets that stand above the reticular surface of the flagellomere (Fig. 3B). Generally, only a single sensillum chaeticum was found in each flagellomere in both sexes. However, two or three sensilla were occasionally observed on a flagellomere. The mean lengths of the spines in male and female moths are shown in Table 1.

Sensilla trichodea.—These slender hairs were the most numerous sensory structures found on the antennae of the pink bollworm. As many as 35 sensilla could be detected on a single flagellomere subsegment. Two types of sensilla trichodea were identified in both male and female moths that corresponded to the descriptions given by Callahan (1965, 1969) and Jefferson et al. (1970) for several other moth species. The Type 1 sensilla trichodea are long and slender with a slight hook at the tip (Figs. 1C, 2C). It was possible to distinguish the sex of a moth by simply observing the more erect disposition of the Type 1 sensory hairs in male moths. The dimorphism was also evident in length measurements of the sensory hairs in males and females, as shown in Table 1; on male moths, they were consistently longer. High magnification scanning electron micrographs revealed that the surface of such sensilla was covered with annular ridges (Fig. 3A), and the base of each hair was inserted into a depression in the reticular network of the subsegment (Fig. 3D). Type 2 sensilla trichodea were relatively shorter and more curved (Figs. 1C, 2B). Under the scanning electron microscope (Fig. 3B), spiral ridges were evident on these sensilla.

Sensilla basiconica.—These sensory peglike structures were about equal in length to the Type 2 sensilla trichodea just described but were inserted into raised sockets (Fig. 1C). The mean length for such sensilla was 20 μm with a range of 17–22 μm. Usually, there were three or four sensilla basiconica on a subsegment, located more or less centrally on the ventral surface. Jefferson et al. (1970) did not report such a structure in the four species of moths that they examined, but Schneider and Steinbrecht (1968) did report them in *Bombyx mori* (L.) as did Callahan (1969) for the corn earworm. Terraced sculpturing was seen on the surface of these sensilla at higher magnifications (Fig. 1D) as described by Callahan (1975).

Sensilla coeloconica.—This sense organ consisted of a circular array of pegs surrounding a depression or pit in the cuticle (Fig. 1C). About four to six of these sensilla were found on a subsegment. They were centrally located on the ventral surface, often in close association with the sensilla basiconica. The "pickets" of the sensilla coeloconica were corrugated as described by Callahan (1975). The mean diameter for such structures is shown in Table 1.

Conclusions

A thorough understanding of the fine structure of a sense organ cannot alone establish its functional significance; some types of behavioral or neurophysiological experiment with each sensillum is required. Recent experiments with single olfactory receptors in species of Lepidoptera (Schneider, 1969; O'Connell, 1975) have demonstrated that sensilla trichodea are responsible for pheromone perception. The entire surface of these sensilla is covered with minute pores. Slifer (1960) found that the presence of such pores can be revealed by the use of permeable dyes. We therefore used the procedures of Slifer in examining the surface of the sensilla trichodea in the pink bollworm and obtained a precipitation of granules of crystal violet within the sensilla trichodea. Thus, such sensilla could function as olfactory receptors in the insect. Moreover, the presence of pheromone-specific receptors on the antennae of this moth has been confirmed by recent electrophysiological recordings from antennae after exposure to air containing pheromone (Cook et al., 1978).

Such evidence coupled with the observed sexual dimorphism of sensilla trichodea suggests that these structures are, in all probability, responsible for pheromone perception in the pink bollworm. Final confirmation must await experiments on single sensilla.

Acknowledgments

We are grateful for the able and conscientious technical assistance of Janice Sweet and David A. Cook.

Literature Cited

Callahan, P. S. 1965. Intermediate and far infrared sensing of nocturnal insects. Part I. Evidences for a far infrared (FIR) electromagnetic theory of cummunication and sensing in moths and its relationship to the limiting biosphere of the corn earworm. Ann. Entomol. Soc. Am. 58: 727–745.

———. 1969. The exoskeleton of the corn earworm moth, *Heliothis zea* (Lepidoptera: Noctuidae) with special reference to the sensilla as polytubular dielectric arrays. Univ. Ga., Agric. Exp. Stn. Res. Bull. 54: 5–105.

———. 1975. Insect antennae with special reference to the mechanism of scent detection and the evolution of the sensilla. Int. J. Insect Morphol. Embryol. 4: 381–430.

Cook, B. J., W. D. Shelton, and R. T. Staten. 1978. Antennal responses of the pink bollworm to gossypiella. Southwest. Entomol. 3: 141–146.

Jefferson, R. N., R. E. Ruben, S. U. McFarland, and H. H. Shorey. 1970. Sex pheromones of noctuid moths. XXII. The external morphology of the antennae of *Trichoplusia ni, Helothis zea, Prodenia ornithogalli,* and *Spodoptera exigua*. Ann. Entomol. Soc. Am. 63: 1227–1238.

O'Connell, R. J. 1975. Olfactory receptor responses to sex pheromone components in the redbanded leafroller moth. J. Gen. Physiol. 65: 179–205.

Schneider, D. 1964. Insect antennae. Annu. Rev. Entomol. 9: 103–122.

———. 1969. Insect olfaction: Deciphering system for chemical messages. Science 163: 1031–1037.

——— and R. A. Steinbrecht. 1968. Checklist of insect olfactory sensilla. *In:* Carthy, J. D. and G. C. Newell, eds., Invertebrate Receptors. Symp. Zool. Soc. Lond. 23: 279–297.

Slifer, E. H. 1960. A rapid and sensitive method for identifying permeable areas in the body wall of insects. Entomol. News 21: 179–225.

Smith, R. K., H. M. Flint, and D. E. Forey. 1978. Air permeation with gossyplure: Feasibility studies on chemical confusion for control of the pink bollworm. J. Econ. Entomol. 71: 257–264.